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Title: Analysis of Conflat Flange Sets Subjected to Internal Pressures

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# **Analysis of Conflat Flange Sets Subjected to Internal Pressures**

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## **Background**

A recent pressure safety walk-down through LANSCE Area B resulted in a request to perform a detailed analysis of certain size conflat flange pairs subject to internal pressures. Though these systems in Area B have performed safely and well for a number of years (with former pressure safety committee approval), it was deemed prudent that an analysis be performed to insure a realistic factor of safety is present in the design as implemented.

## **Analysis Details**

The specific conflat flange sizes to be analyzed are 2.75 inch (with 1.5 inch OD, .065 inch wall tubing), 3.375 inch (with 1.5 inch OD, .065 inch wall tubing) and 4.625 inch (with 3.0 inch OD, .065 inch wall tubing). All models are performed using room temperature material data with 285 psi internal pressure (where the system relieves internal pressure). In all cases, one flange in the pair is non-rotatable, and the other is rotatable.

In all cases, bolts are included in the analysis and pre-loaded in tension, calculated by using eq. 10.12 of Juvinall and Marshek [1] with torque specification given by MDC (vendor) for the size in question ([www.mdcvacuum.com](http://www.mdcvacuum.com)).

$$T = 0.2F_id$$

This is an approximate relationship based on average thread friction conditions.

## **Mechanical Analyses**

### ***General Analysis Assumptions***

The assembly was modeled with appropriate boundary conditions applied to simulate a bolted flange pair subject to internal pressure. The software used to perform the analyses was ANSYS Workbench v12.0. Geometry was ported to ANSYS via an .x\_t

(parasolid) translation from the original SolidWorks model. All components, except for the copper gasket, are modeled as 304 stainless steel. This is the material that flanges are fabricated from. Table 1 shows the mechanical properties of 304 stainless steel.

Density	8.00 g/cc	0.289 lb/in <sup>3</sup>
Ultimate Tensile Strength	505 MPa	73.2 ksi
Tensile Yield Strength	215 MPa	31.2 ksi
Elongation at Break	70%	70%
Modulus of Elasticity	193 GPa	28000 ksi

**Table 1.** The mechanical properties of 304 stainless steel. Data courtesy Matweb.com

Table 2 shows the mechanical properties of alloy 101 copper.

Density	8.94 g/cc	0.323 lb/in <sup>3</sup>
Ultimate Tensile Strength	221 MPa	32.1 ksi
Tensile Yield Strength	69 MPa	10.0 ksi
Elongation at Break	55%	55%
Modulus of Elasticity	115 GPa	16700 ksi

**Table 2.** The mechanical properties of alloy 101 copper. Data courtesy Matweb.com

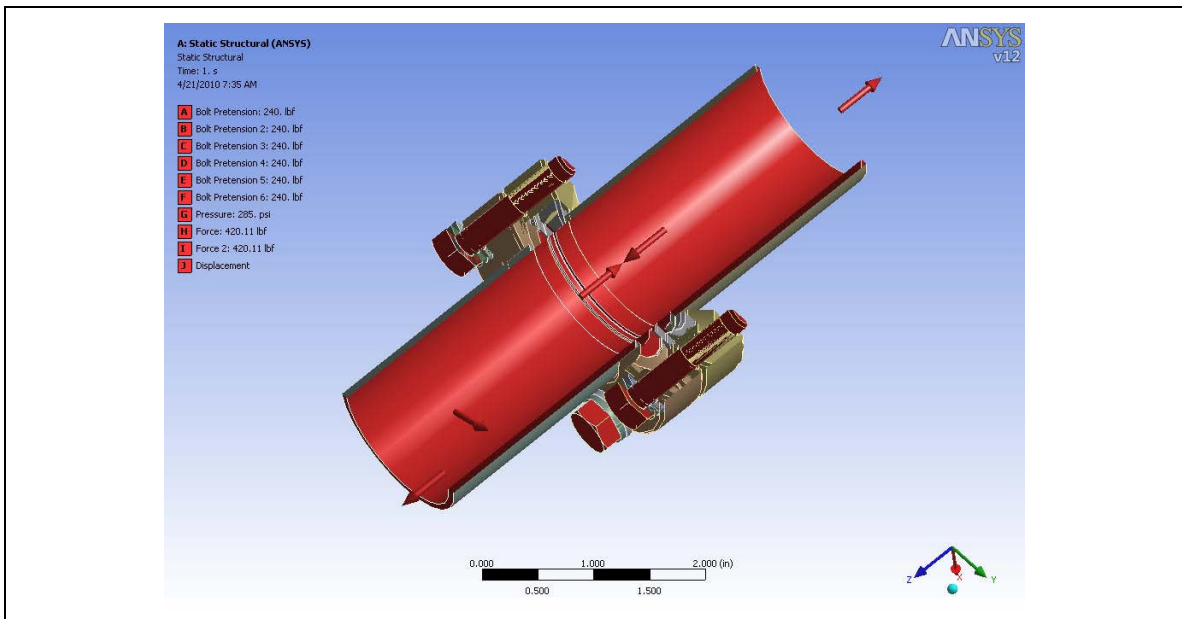
## ***Analysis Details and Results***

### ***2.75" Conflat Flange Pair***

Figure 1 shows the basic model assembly as it appears in SolidWorks. Figure 2 shows the boundary conditions for the model.

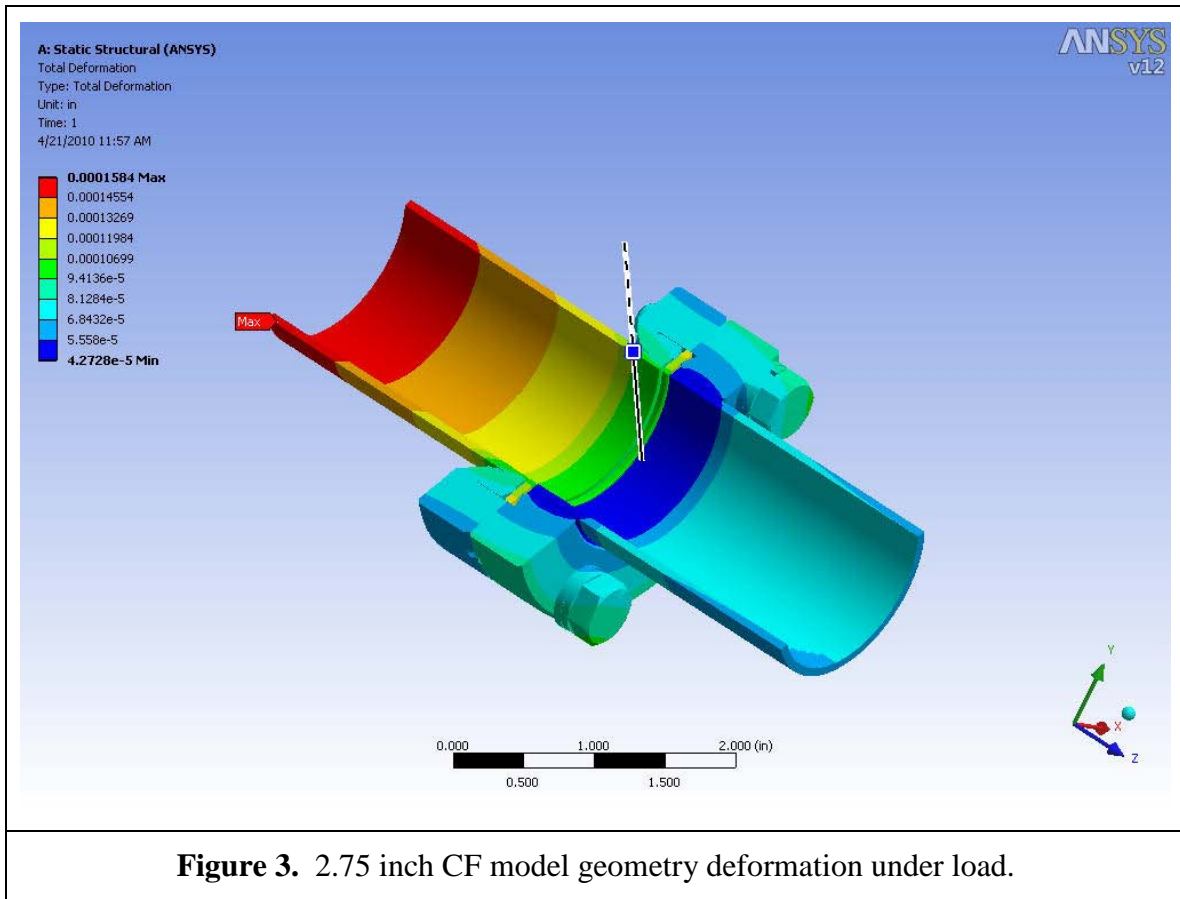


**Figure 1.** Overall 2.75 inch CF model geometry

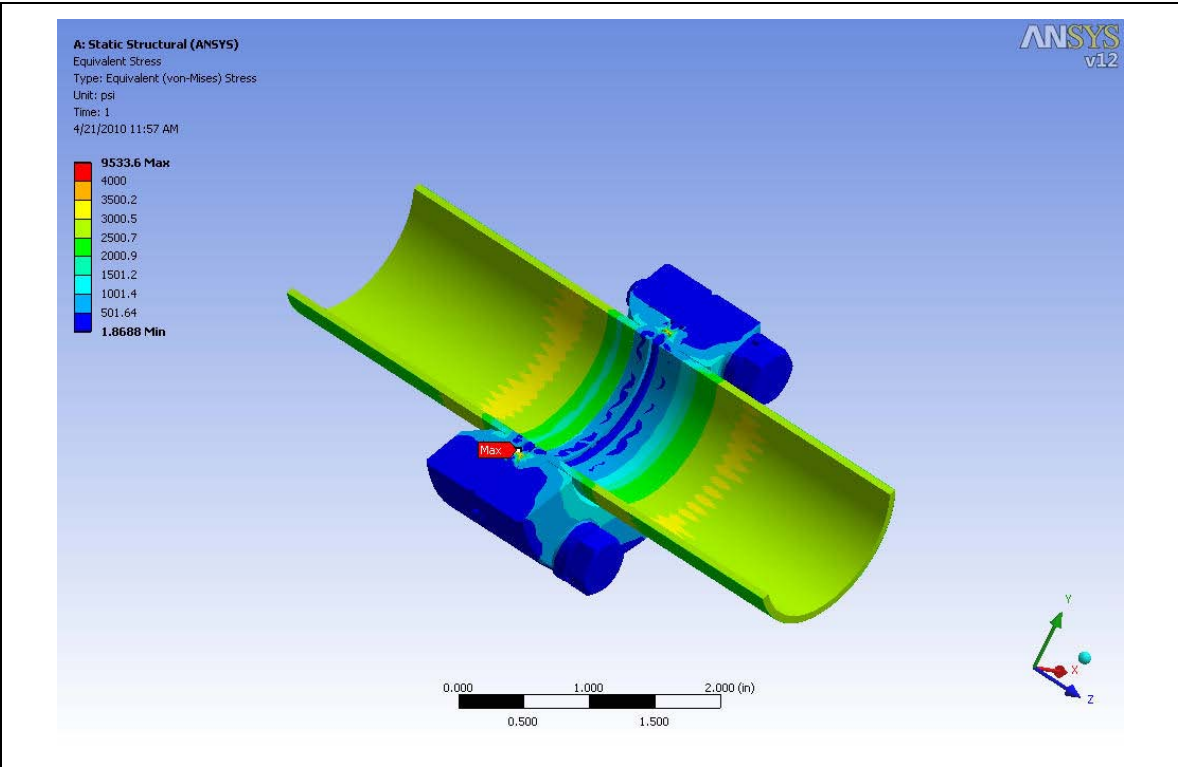


**Figure 2.** 2.75 inch CF model geometry boundary conditions.

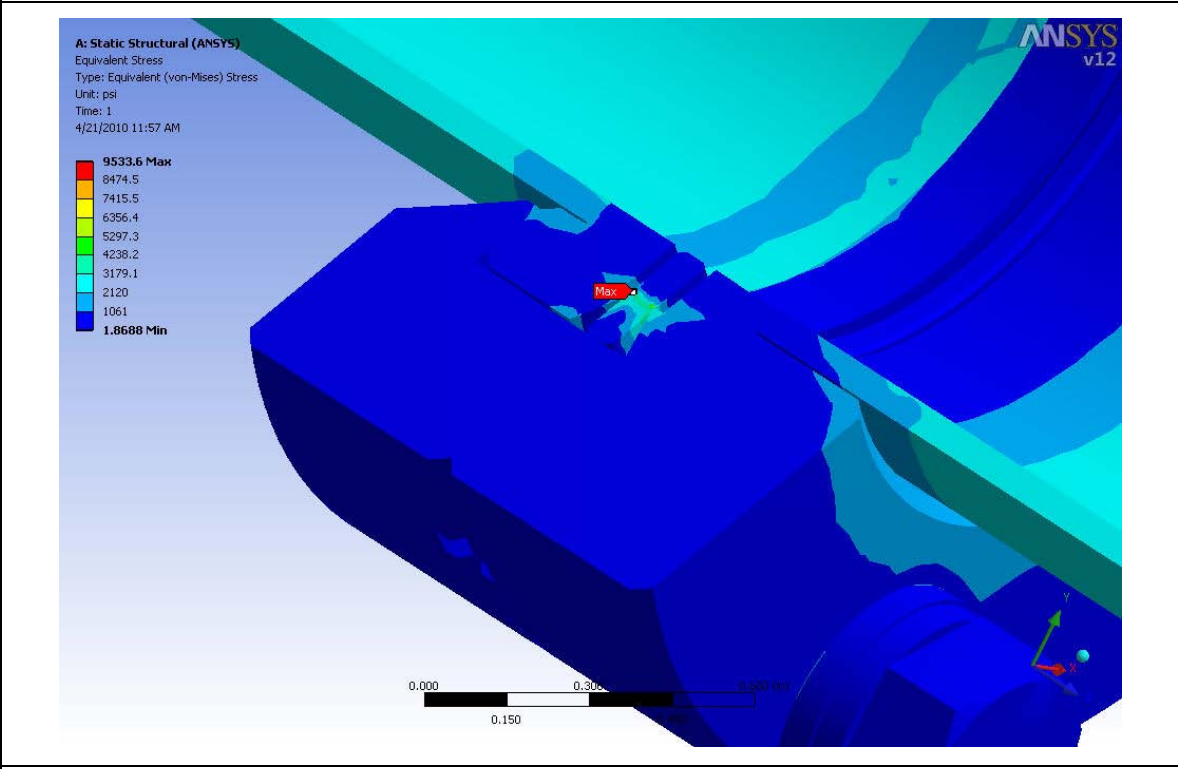
Figure 3 shows the deformation under these applied conditions, and Figures 4 and 5 show the equivalent stress incurred by the structure as these loads are applied.



The main stress concentration occurs in the copper gasket. It is highly concentrated, and Figure 5 shows a detail view highlighting this concentration. Under such a concentrated condition, the copper will yield and deform to alleviate the stress. All other stresses are well below allowable for the 304 stainless steel.



**Figure 4.** 2.75 inch CF model geometry stress distribution under load.



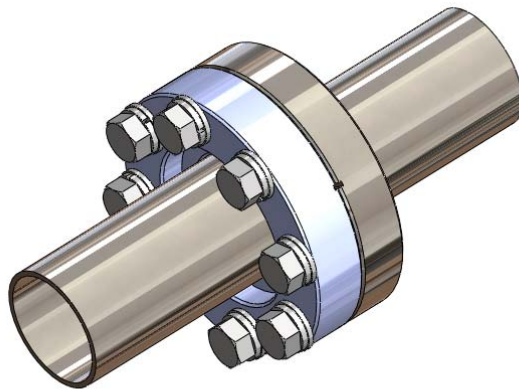
**Figure 5.** 2.75 inch CF model geometry stress distribution under load detail.

Per ASME Section VIII Division I Appendix 2, Part C, the shearing stress carried by the weld shall not exceed  $0.8S_n$ , where  $S_n$  is the allowable stress in the neck material. In this case, the neck material, 304 stainless steel, has an allowable stress of 17,600 psi. So the weld shear stress is  $0.8 * 17,600 \text{ psi} = 14,080 \text{ psi}$ . Assuming a conservative 0.04 inch weld penetration in the 0.065 inch tube wall, the weld stress area is 0.18 square inches. The stress imparted by axial tube forces from pressure is  $420.11 \text{ lbs}/.18\text{in}^2 = 2,332 \text{ psi}$ , a factor of 6 less than the 14,080 psi allowable stress.

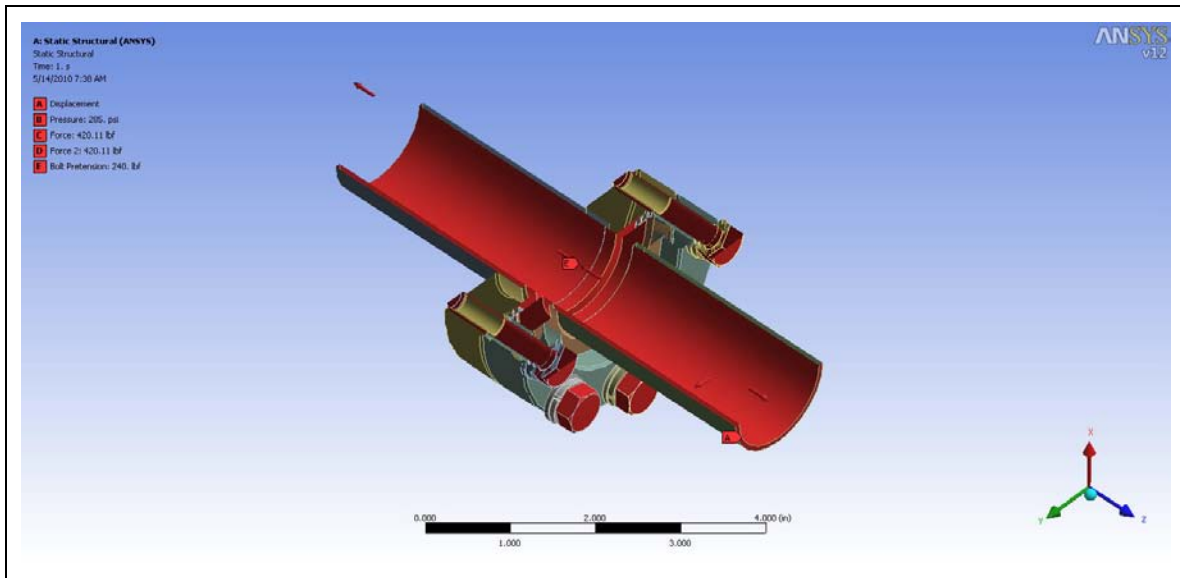
The resultant stresses and deformations are well within acceptable limits for the flange pair when loaded in this manner.

### ***3.375" Conflat Flange Pair***

Figure 6 shows the basic model assembly as it appears in SolidWorks. Figure 7 shows the boundary conditions for the model.

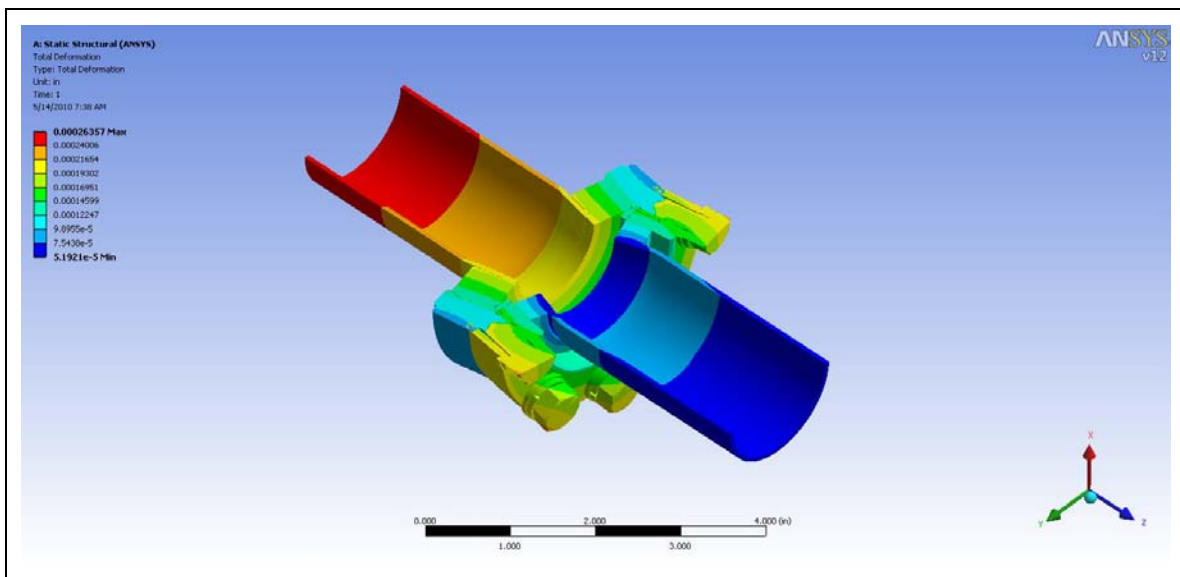


**Figure 6.** Overall 3.375 inch CF model geometry



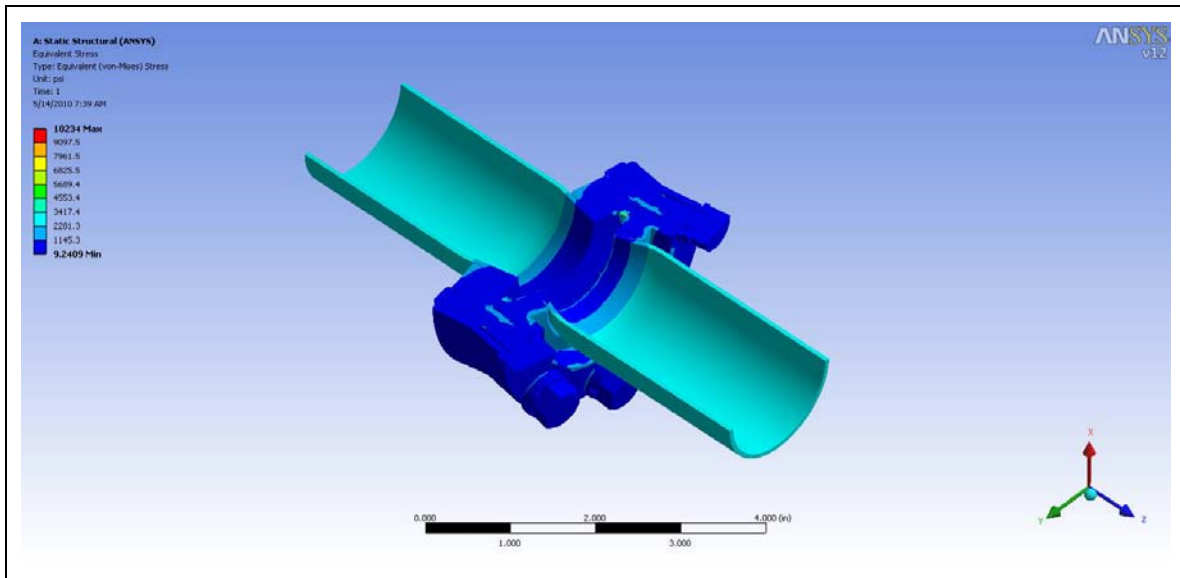
**Figure 7.** 3.375 inch CF model geometry boundary conditions.

Figure 8 shows the deformation under these applied conditions, and Figures 9 and 10 show the equivalent stress incurred by the structure as these loads are applied.

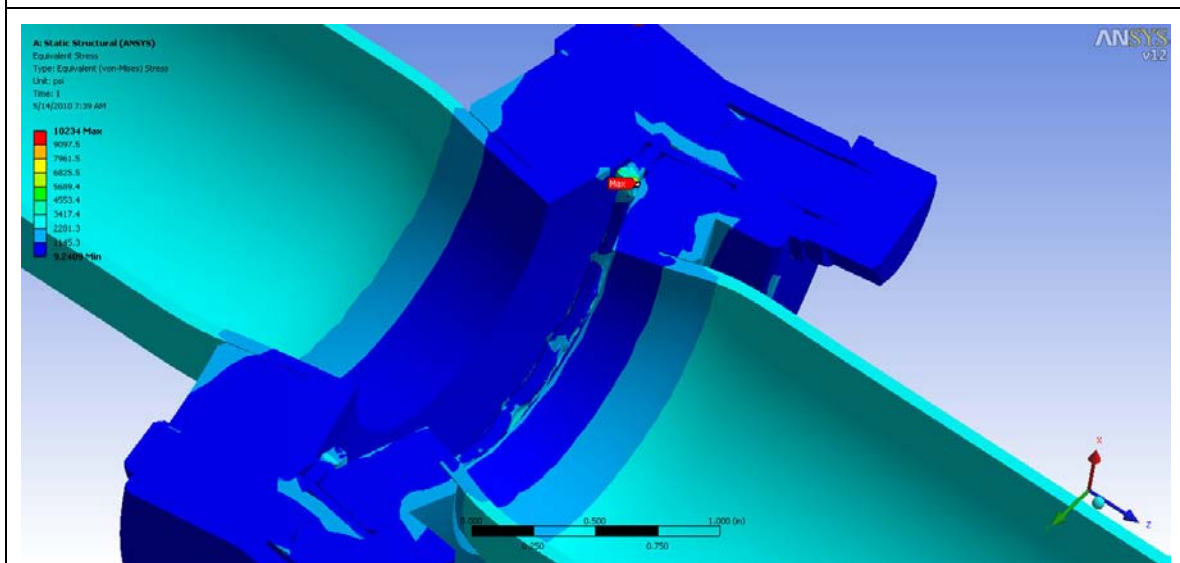


**Figure 8.** 3.375 inch CF model geometry deformation under load.

The main stress concentration occurs in the copper gasket. It is highly concentrated, and Figure 10 shows a detail view highlighting this concentration. Under such a concentrated condition, the copper will yield and deform to alleviate the stress. All other stresses are well below allowable for the 304 stainless steel.



**Figure 9.** 3.375 inch CF model geometry stress distribution under load.



**Figure 10.** 3.375 inch CF model geometry stress distribution under load detail.

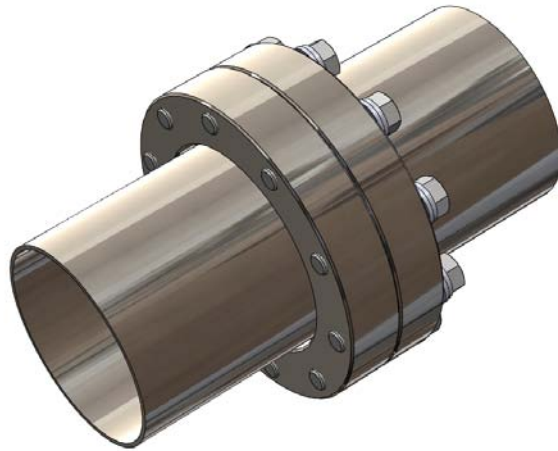
Per ASME Section VIII Division I Appendix 2, Part C, the shearing stress carried by the weld shall not exceed  $0.8S_n$ , where  $S_n$  is the allowable stress in the neck material. In this case, the neck material, 304 stainless steel, has an allowable stress of 17,600 psi. So the weld shear stress is  $0.8 * 17,600 \text{ psi} = 14,080 \text{ psi}$ . Assuming a conservative 0.04 inch weld penetration in the 0.065 inch tube wall, the weld stress area is 0.18 square inches.

The stress imparted by axial tube forces from pressure is  $420.11 \text{ lbs}/.18\text{in}^2 = 2,332 \text{ psi}$ , a factor of 6 less than the 14,080 psi allowable stress.

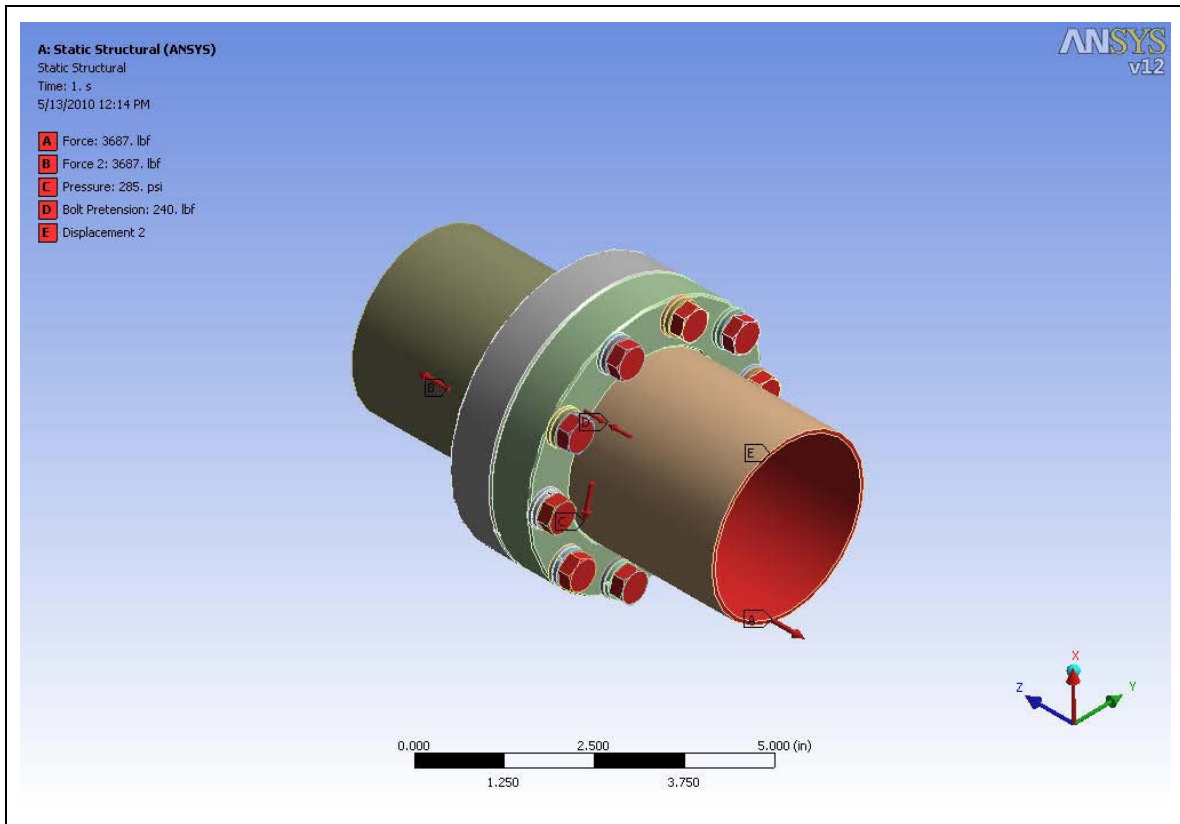
The resultant stresses and deformations are well within acceptable limits for the flange pair when loaded in this manner.

#### ***4.625" Conflat Flange Pair***

Figure 11 shows the basic model assembly as it appears in SolidWorks. Figure 12 shows the boundary conditions for the model.

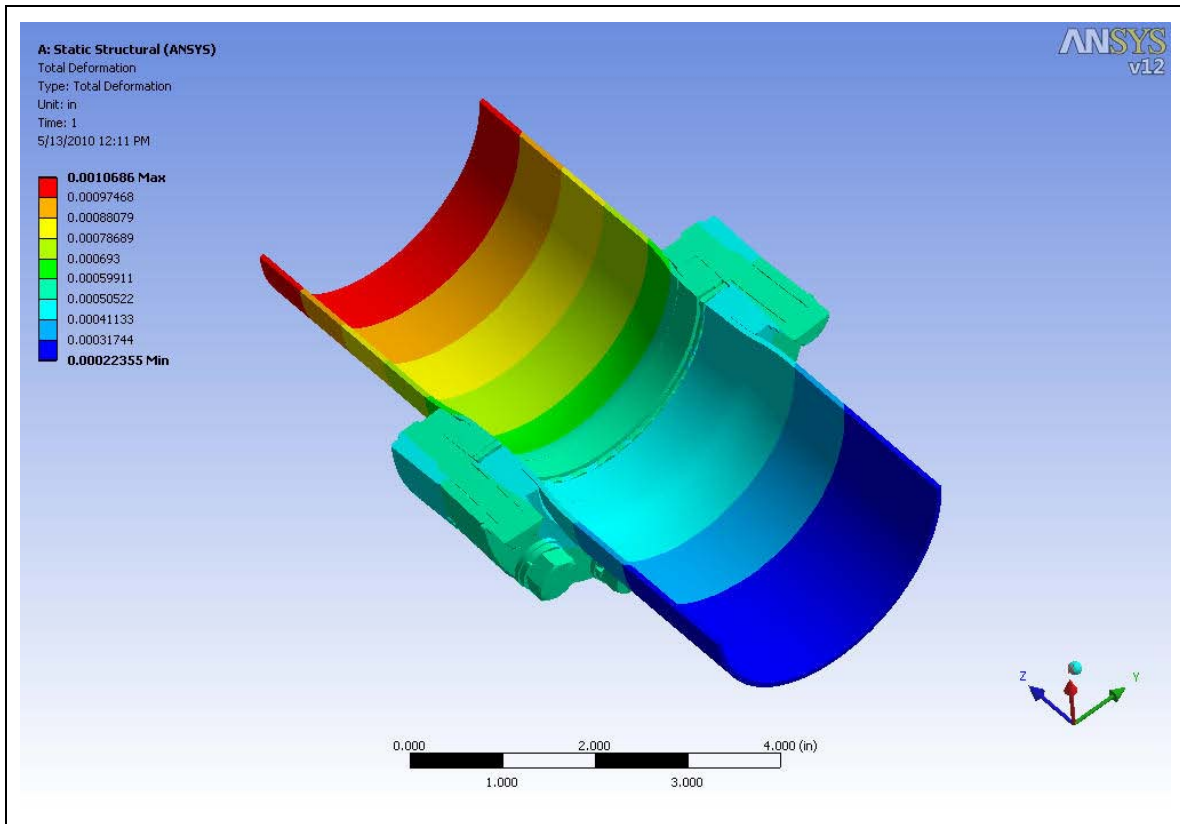


**Figure 11.** Overall 4.625 inch CF model geometry



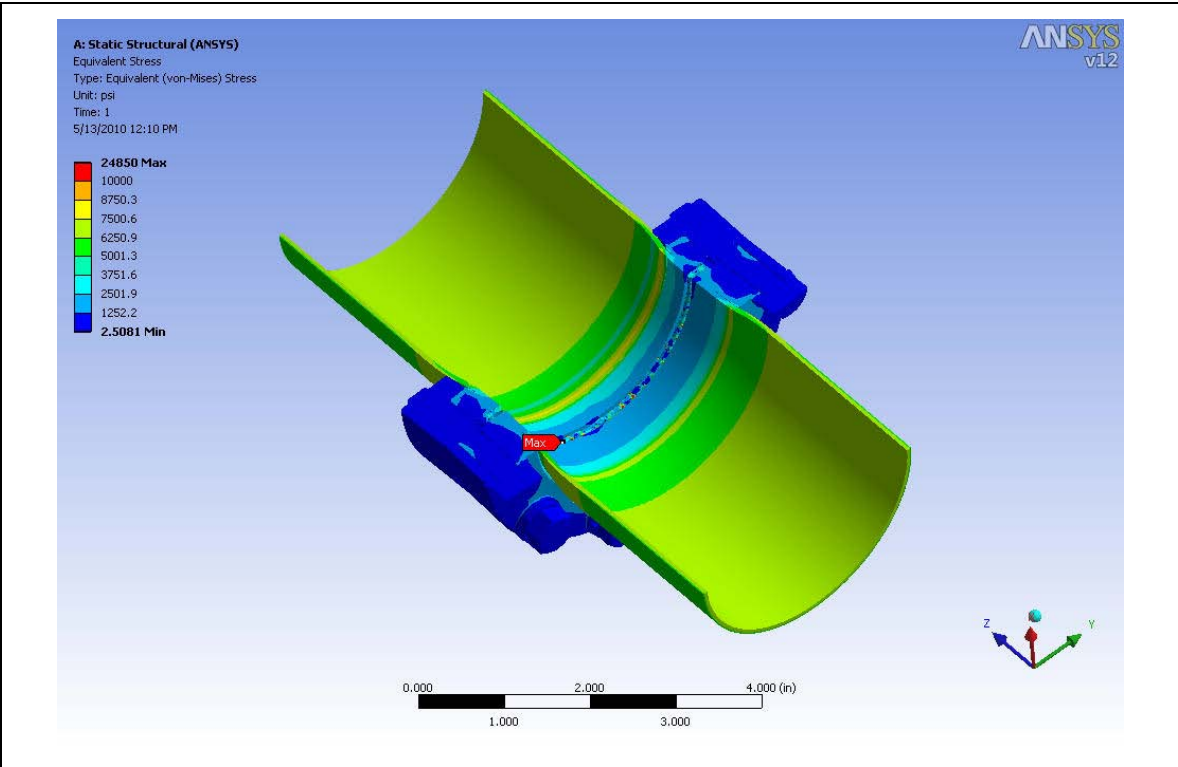
**Figure 12.** 4.625 inch CF model geometry boundary conditions.

Figure 13 shows the deformation under these applied conditions, and Figures 14 and 15 show the equivalent stress incurred by the structure as these loads are applied.

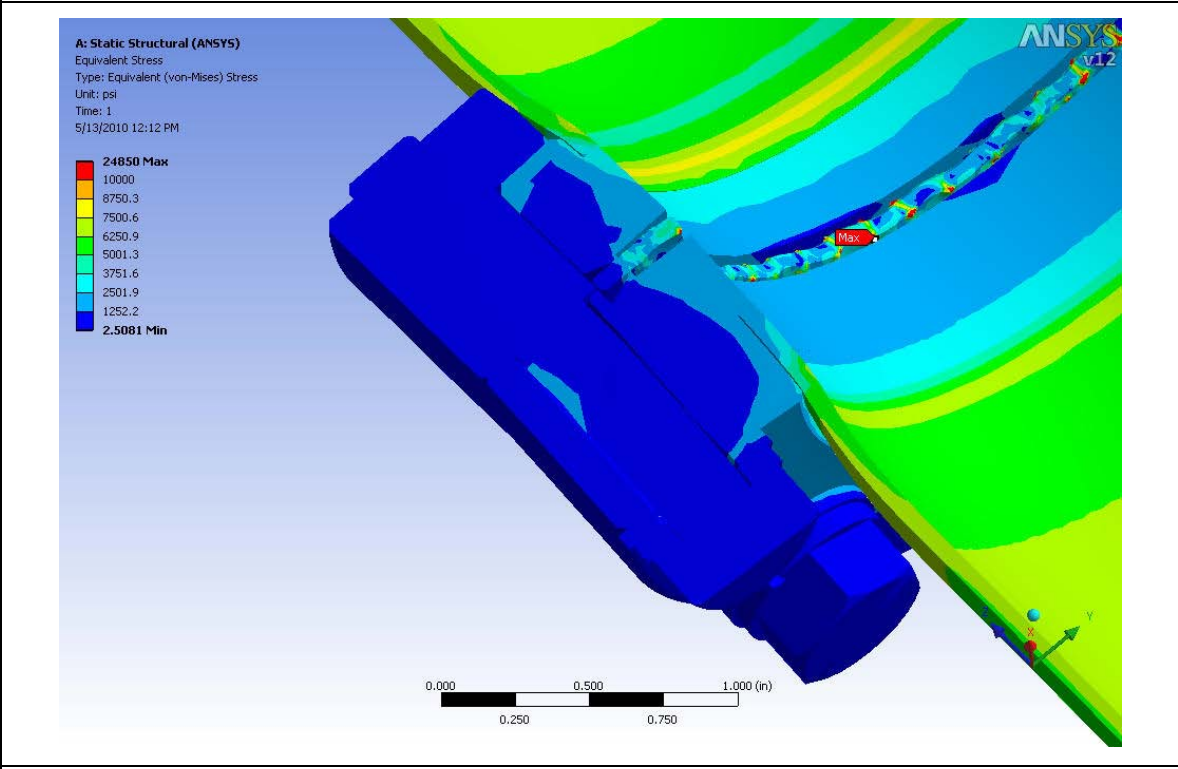


**Figure 13.** 4.625 inch CF model geometry deformation under load.

The main stress concentration occurs in the copper gasket. It is highly concentrated, and Figure 15 shows a detail view highlighting this concentration. Under such a concentrated condition, the copper will yield and deform to alleviate the stress. All other stresses are well below allowable for the 304 stainless steel.



**Figure 14.** 4.625 inch CF model geometry stress distribution under load.



**Figure 15.** 4.625 inch CF model geometry stress distribution under load detail.

Per ASME Section VIII Division I Appendix 2, Part C, the shearing stress carried by the weld shall not exceed  $0.8S_n$ , where  $S_n$  is the allowable stress in the neck material. In this case, the neck material, 304 stainless steel, has an allowable stress of 17,600 psi. So the weld shear stress is  $0.8 * 17,600 \text{ psi} = 14,080 \text{ psi}$ . Assuming a conservative 0.04 inch weld penetration in the .065 inch tube wall, the weld stress area is 0.365 square inches. The stress imparted by axial tube forces from pressure is  $3,687 \text{ lbs}/.365\text{in}^2 = 10,100 \text{ psi}$ , which is less than the 14,080 psi allowable stress.

The resultant stresses and deformation are distinctly within acceptable limits for the flange pair when loaded in this manner.

## **Conclusions**

These finite element studies indicate that, for the described loads, analyzed conflat flanges can withstand the pressures they are subjected to at LANSCE Area B with reasonable safety factors.

## **References**

Juvinall, Robert C., and Kurt M. Marshek, Fundamentals of Machine Component Design, 2<sup>nd</sup> Edition, John Wiley and Sons, New York. P 367.